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Automic Change Detection and Classification (ACDC) System

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Introduction: The authors are developing an Automated Change Detection and Classification (ACDC) system for the Mine Warfare (MIW) group at the Naval Oceanographic Office (NAVOCEANO). ACDC detects features in sidescan imagery, classifies the features (e.g., as minelike or not), and searches through historical databases of previously detected features to perform change detection (i.e., to determine whether the feature is new or pre-existing, relative to earlier surveys). The completed ACDC system will assist mine countermeasures (MCM) warfighters to more quickly and reliably identify minelike contacts in sidescan, thereby reducing warfighter fatigue, reducing risk to the warfighter, and shortening timelines for completion of MCM objectives.

ACDC consists of five major components: (1) clutter detection, (2) feature completion/classification, (3) geospatial searching, (4) clustering, and (5) scene matching. Depending on the quality of sidescan imagery to be analyzed, each of these steps can be performed autonomously (i.e., with no human intervention) or as a computer-assisted function (in which ACDC suggests statistically likely outcomes to the operator, who makes a final determination).

Clutter Detection: Minelike objects, also called minelike echoes or simply clutter, show up in sidescan imagery as bright spots, with adjacent shadows facing perpendicularly away from the center of the scan track, or nadir. ACDC includes a real-time algorithm that detects these bright spots and shadows by using a pair of geospatial bitmaps. Each pixel in the small "snippet" of imagery containing the object is assigned a corresponding bit in both bitmaps (Fig. 8). All bits in both bitmaps are initially cleared (value = 0). Each pixel in the image snippet that is brighter than some predetermined bright intensity threshold triggers a "set bit" (bit value = 1) in the bright spot bitmap, while each snippet pixel that is darker than a predetermined shadow intensity threshold sets a bit in the shadow bitmap. The clutter-detection algorithm compares the two bitmaps (using Boolean operations) to determine whether there is a bright spot and adjacent shadow in the appropriate configuration to be considered an object of interest. The algorithm outputs a confidence level to indicate whether the object should be analyzed further (i.e., how likely it is minelike). The operator can choose to manually review the objects and confidence levels, selecting those to be processed further, or the algorithm can run autonomously, such that objects with confidence levels greater than some predefined threshold will be automatically selected for the next phase of ACDC processing.

Feature Completion and Classification: Features of various shapes and sizes are traditionally discerned in sidescan by the shadow's dimensions, which vary as a function of both beam angle and feature size.[1] Shadows are detected more easily and reliably than bright spots in sidescan; bright spots often appear smaller or larger than the actual object. ACDC corrects this by using an adaptive filter to "complete" the feature's bright spot, reducing or enlarging it based on the shadow. The feature then can be classified more accurately by using dimensions of both the shadow and the completed bright spot. The filter outputs a snippet of imagery that contains only three gray-scale values: black for shadow bits, white for completed bright spot bits, and gray for all other bits (Fig. 9).

Geospatial Search: ACDC's geospatial search algorithm searches historical databases, such as the NAVOCEANO Master Contact Data Base (MCDB), to find previously detected features that are spatially close to each newly detected feature. The MCDB contains imagery from past sidescan surveys, along with snippets and descriptive attributes of classified features from those surveys. The search algorithm attempts to match each newly detected feature with spatially close historical features while correcting for estimated position errors (e.g., feature migration and Global Positioning System errors) in both the new and historical features. If no matches are successful, the newly detected feature is marked as a new object not seen before in the historical data. If a single match is made (i.e., one historical feature matches the new feature), they are assumed to be the same. If more than one historical feature matches a new feature, ACDC passes the new feature and all possible historical matching features to the next phase of processing.

Scene Matching: The final phase of ACDC—change detection—will be accomplished via two scene-matching algorithms being developed this year. A *feature-matching* algorithm will input wavelet coefficients to a neural network and match historical features (extracted during the geospatial search) with newly detected features. Wavelet networks have been proven to match complex features well, e.g., in face recognition.[2] To reduce the numerous false detections

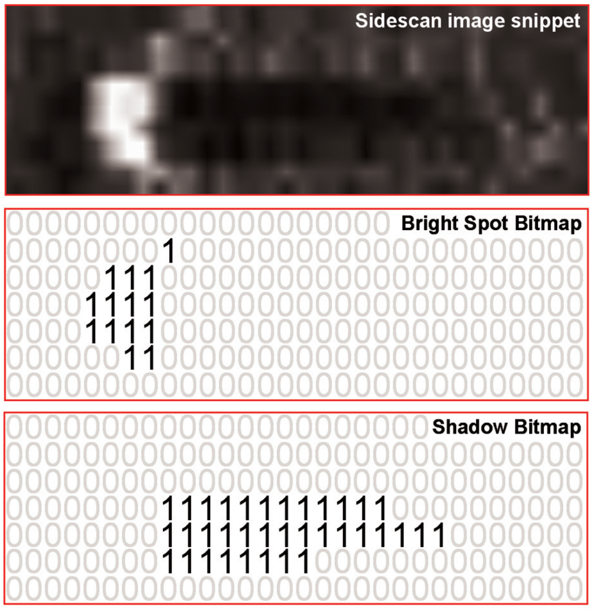

FIGURE 8
Geospatial bitmaps are used to detect bright spots and shadows in sidescan imagery.

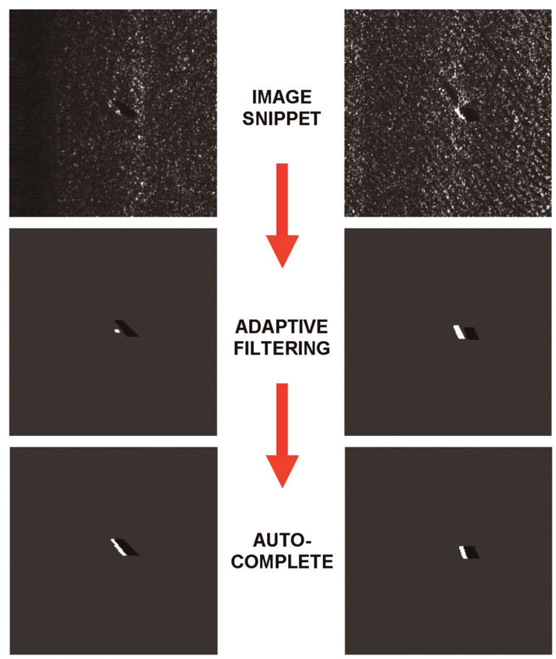

FIGURE 9
A feature's bright spot is "completed," based on its shadow. In the series on the left, the bright spot is enlarged to match the shadow. On the right, the bright spot is reduced.

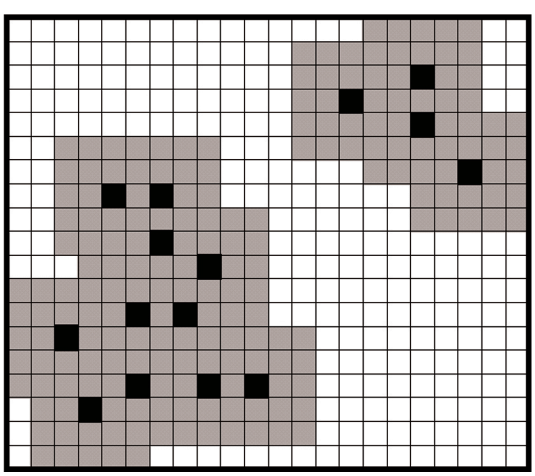

FIGURE 10
Geospatial bitmaps are used to cluster geographically close points.

common during feature matching, an *area-matching* algorithm will match bounded regions of clustered features with corresponding regions of historical features, using another wavelet network and a single-pass clustering algorithm, described below.

Clustering: The authors developed the Geospatial Bitmap (GB) clustering algorithm as a fast, efficient, and repeatable method of clustering into bounded regions any set of unique elements, defined by any coordinate system, lying in *n*-dimensional space.[3] The clustering is accomplished by mapping each element into one or more predefined geometric "expansion shapes" using GBs. Any mapping resulting in a shape with dimension less than or equal to the dimension of the element space can define a cluster. Thus, two-dimensional (2D) clustering (e.g., clustering minelike elements in sidescan imagery) can be accomplished by expanding the elements into ellipses, rectangles or triangles, while 3D clustering can use spheroids, boxes, or cones. Elements that grow together will be contained within a common cluster (Fig. 10).

The GB clustering algorithm is a good choice for applications that require automated clustering in realtime: it is single-pass (i.e., noniterative), requires no seed points, and is order-independent (i.e., the ordering of elements has no effect on the resultant clusters). In addition to clustering the elements, the algorithm produces a bounded polygon to define each cluster boundary and calculates a measure of clutter density, which is the number of clustered elements divided by the area of the cluster polygon. ACDC uses this clustering algorithm to identify regions of high, medium, and low clutter density in sidescan. MCM warfighters use clutter density to determine whether an area of interest should be swept for mines prior to an operation.

Summary: The authors are developing ACDC to assist MCM warfighters in more quickly, reliably, and consistently identifying minelike contacts in sidescan imagery, thereby reducing warfighter fatigue, reducing risk to the warfighter, and significantly shortening timelines for completion of MCM objectives. Algorithms to perform clutter detection, feature completion and classification, geospatial searches of historical data, and clustering have been developed and demonstrated during recent naval exercises, including CCOA Delta Box/USS *Scout* (Ingleside Naval Base), BLUEGAME (Norway), and CJTFEX-04 (Camp Lejeune). Scene-matching algorithms are being developed this year to provide ACDC with a near-real-time change detection capability, in both computer-assisted and fully autonomous modes.

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